

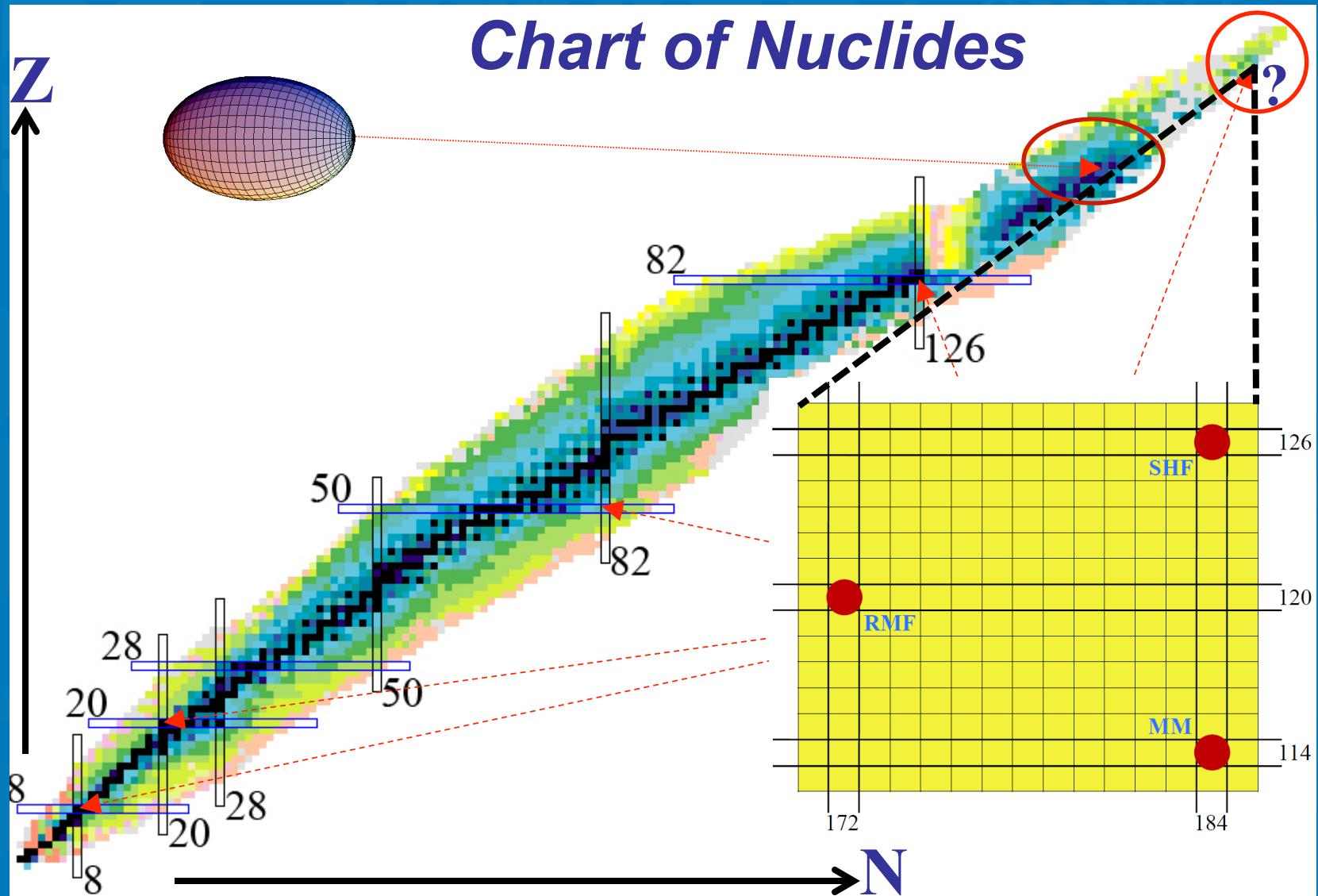
High-spin Structure of Neutron-rich $^{248-250}\text{Cf}$ ($N=150$ - 152)

Sankha S. Hota

University of Massachusetts Lowell

Work supported by the U. S. Department of Energy

Heavy and superheavy elements



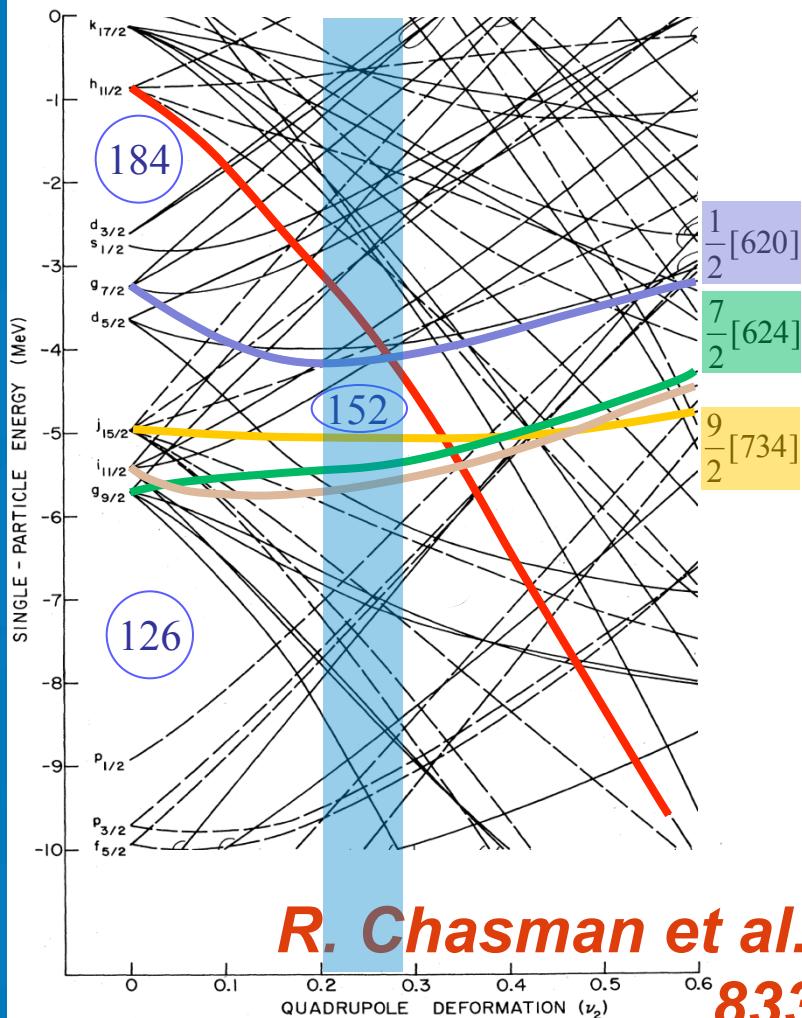
Investigating single-

particle orbitals

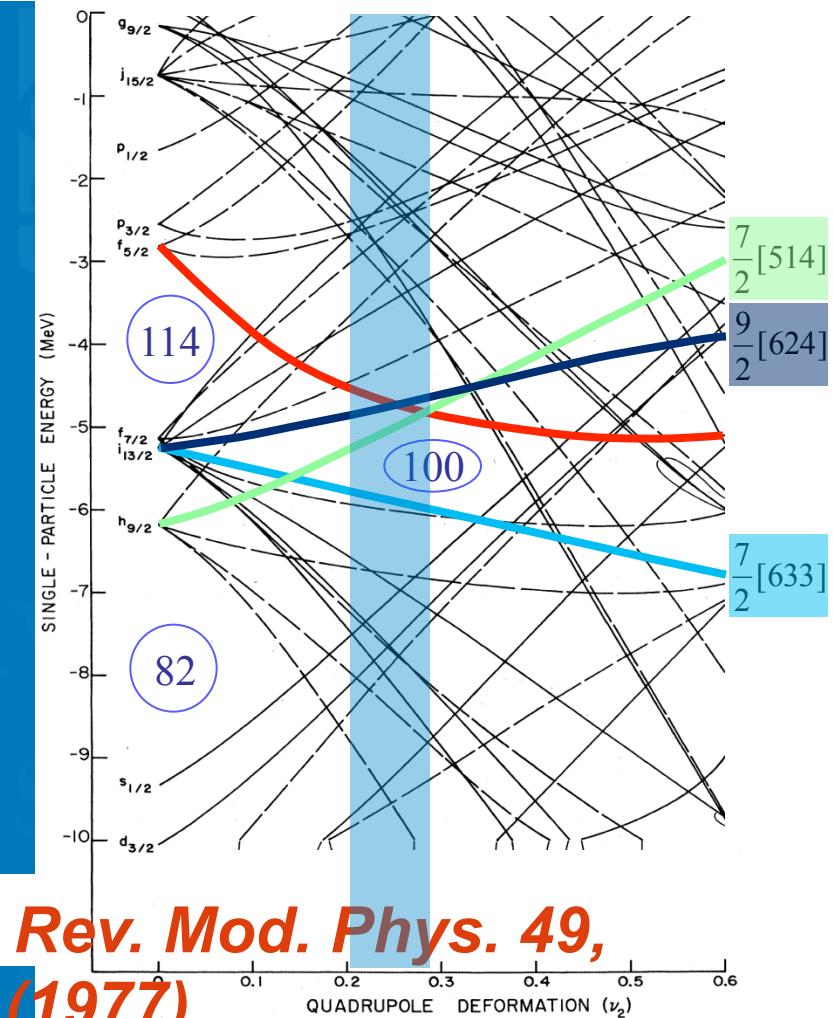
Neutrons

Woods-Saxon

Protons

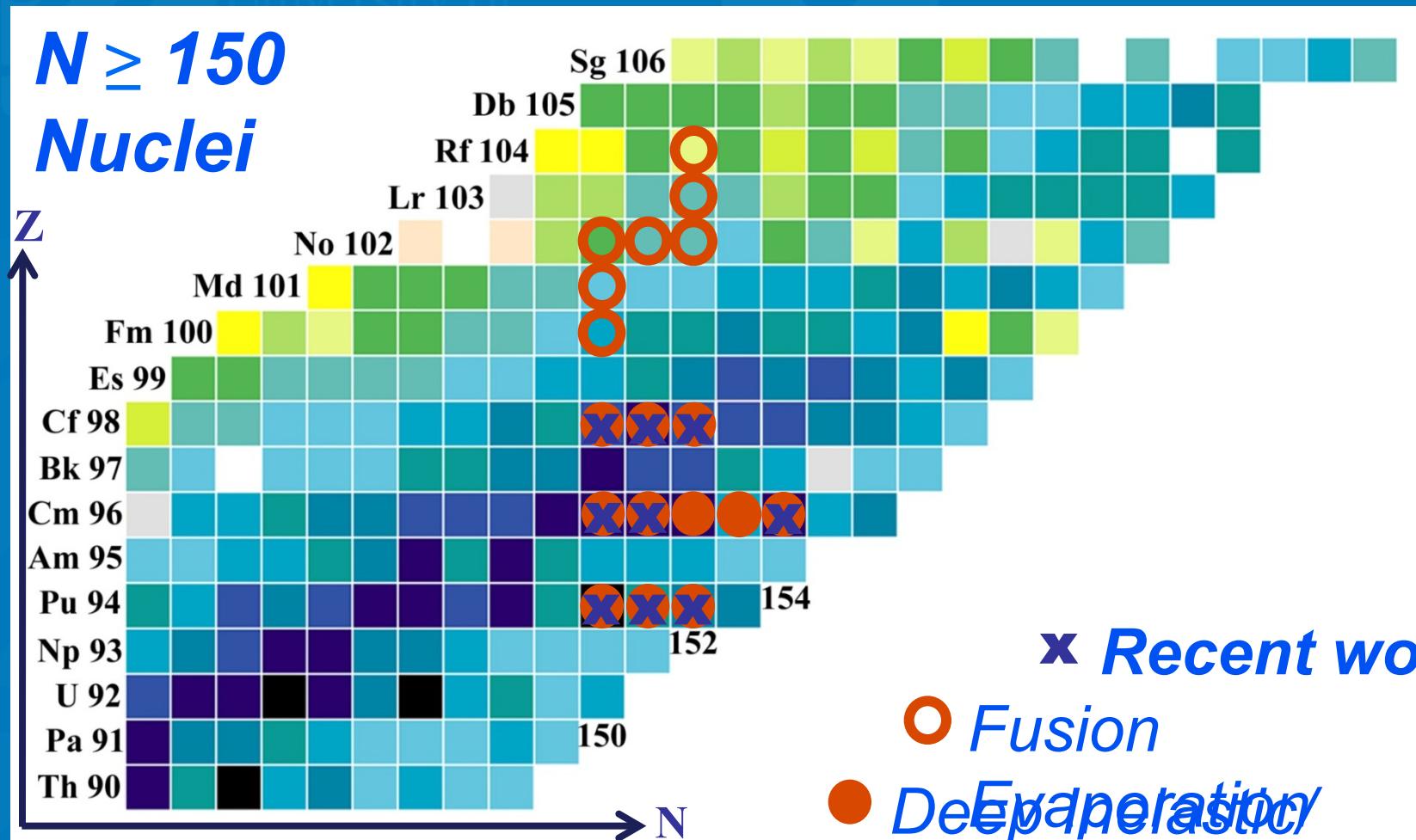


833 (1977)



Isotopes investigated in the $A \sim 250$ region

Rotational bands ($I \approx 20^+$)



Recent Experiments – UML & ANL collaboration

ATLAS + Gammasphere ~15% above
Prompt Spectroscopy

^{209}Bi (1450 MeV) on $^{248}\text{Cm}^{246,247,248,249,250}\text{Cm}$

^{208}Pb (1430 MeV) on $^{244}\text{Pu}^{244,245,246}\text{Pu}$

$^{207,208}\text{Pb}$ (1430 MeV) on $^{249}\text{Cf}^{248,249,250}\text{Cf}$

^{208}Pb (1460 MeV) on ^{251}Cf performed

Earlier successful prompt spectroscopy using

PHYSICAL REVIEW C

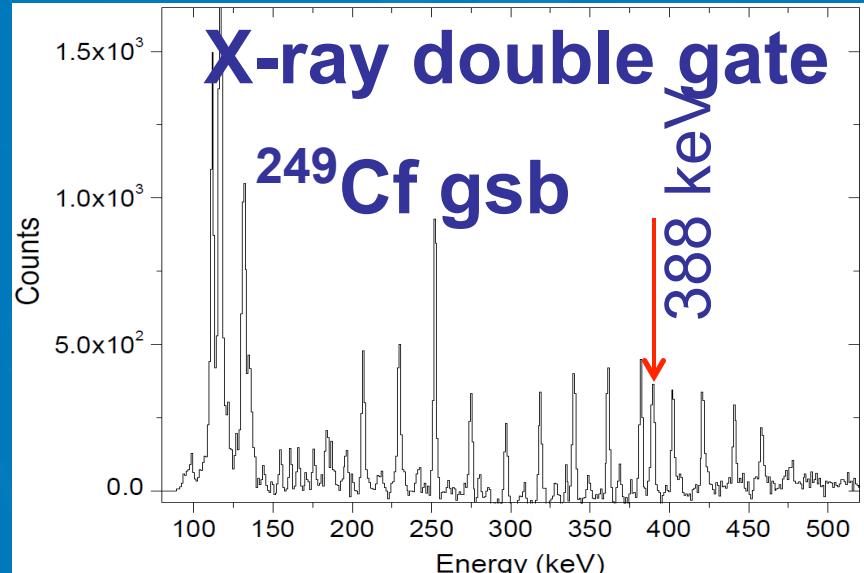
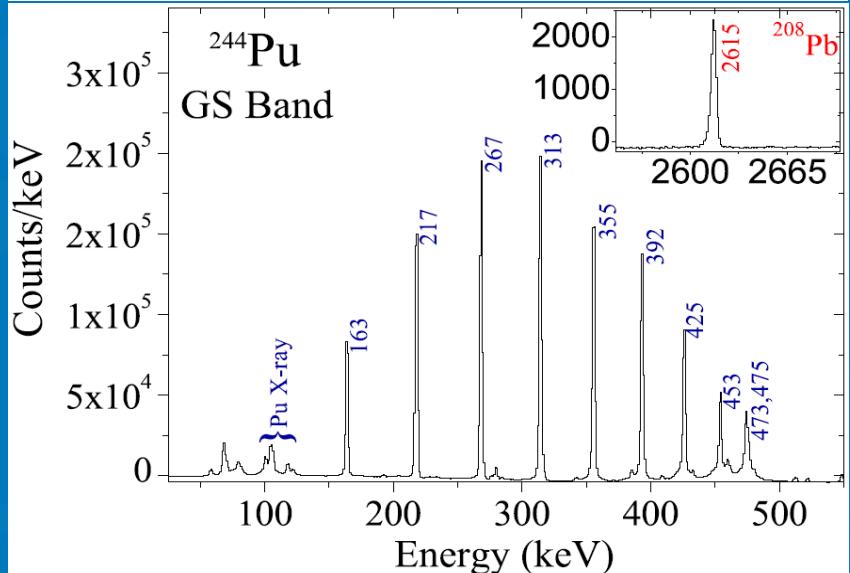
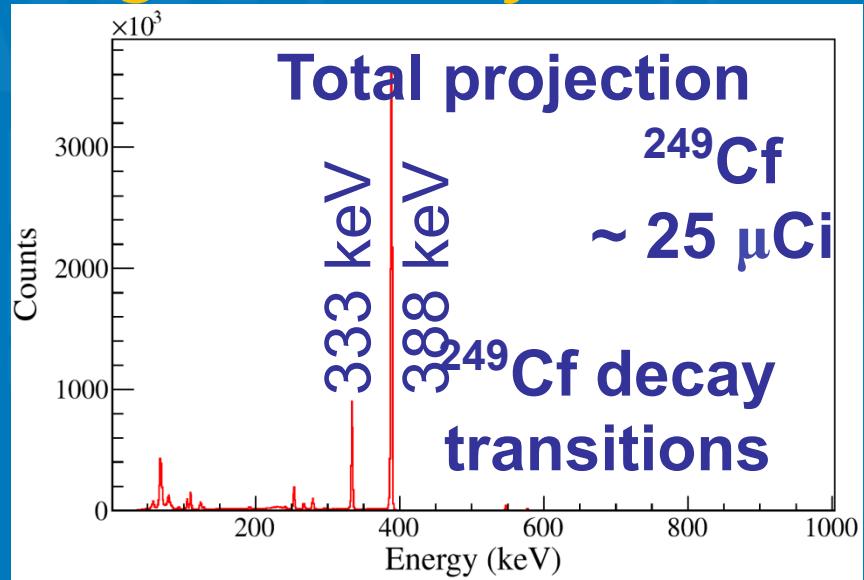
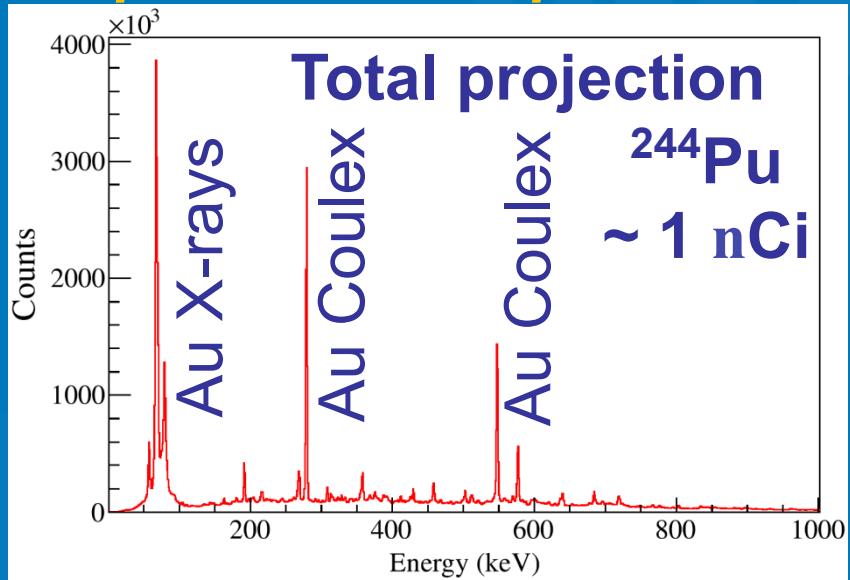
VOLUME 57, NUMBER 3

MARCH 1998

High-spin properties of octupole bands in ^{240}Pu and ^{248}Cm

G. Hackman,¹ R. V. F. Janssens,¹ T. L. Khoo,¹ I. Ahmad,¹ J. P. Greene,¹ H. Amro,^{1,2} D. Ackermann,^{1,*} M. P. Carpenter,¹ S. M. Fischer,¹ T. Lauritsen,¹ L. R. Morss,¹ P. Reiter,¹ D. Seweryniak,¹ D. Cline,³ C. Y. Wu,³ E. F. Moore,² and T. Nakatsukasa⁴

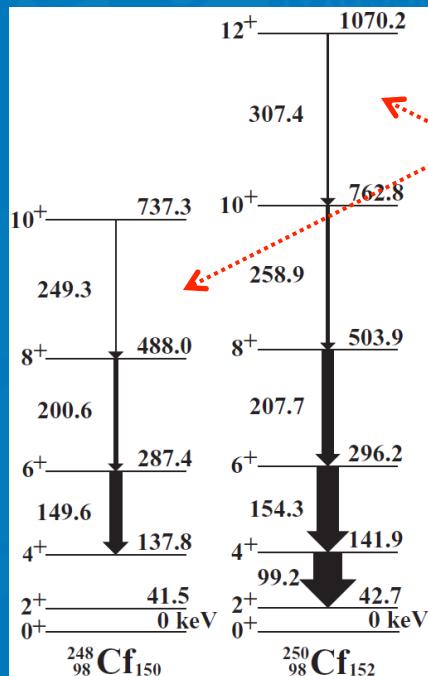
Spectroscopic challenges: analysis, identification



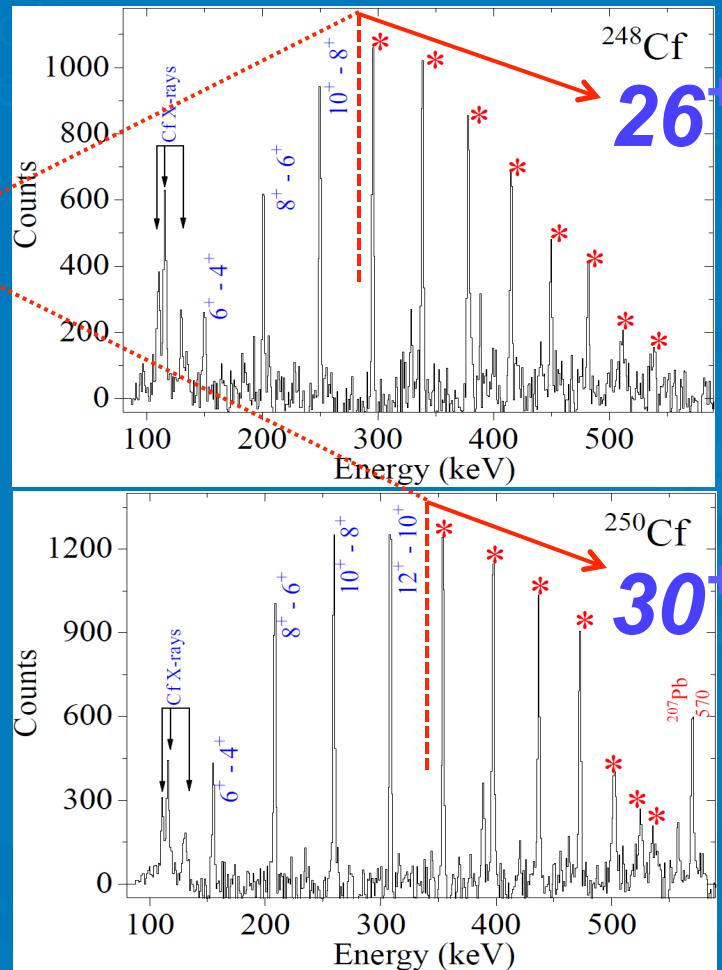
results - $^{248,250}\text{Cf}$ ($Z = 98$, $N = 150, 152$)

^{208}Pb on ^{249}Cf

^{18}O on $^{249,250,251}\text{Cf}$



R. Takahashi et al.,
PRC 81, 057303
(2010)



Manuscript in preparation, S. S. Hota et al.

Coincidence
with

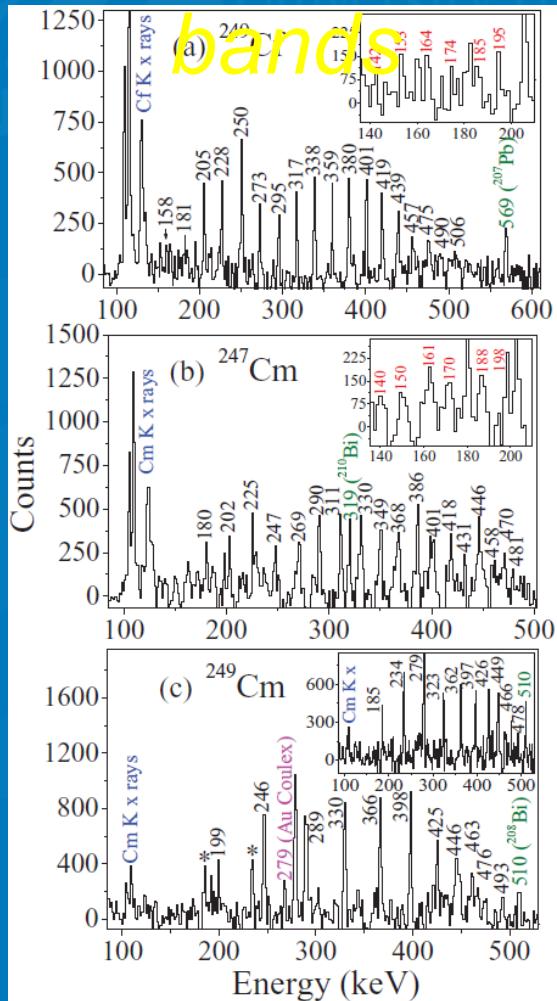
Cf X-rays

Binary
reaction
partner

Known
members
of ground
state
band

Z , odd- N isotopes – $^{247,249}\text{Cm}$ and ^{249}Cf

Ground state bands

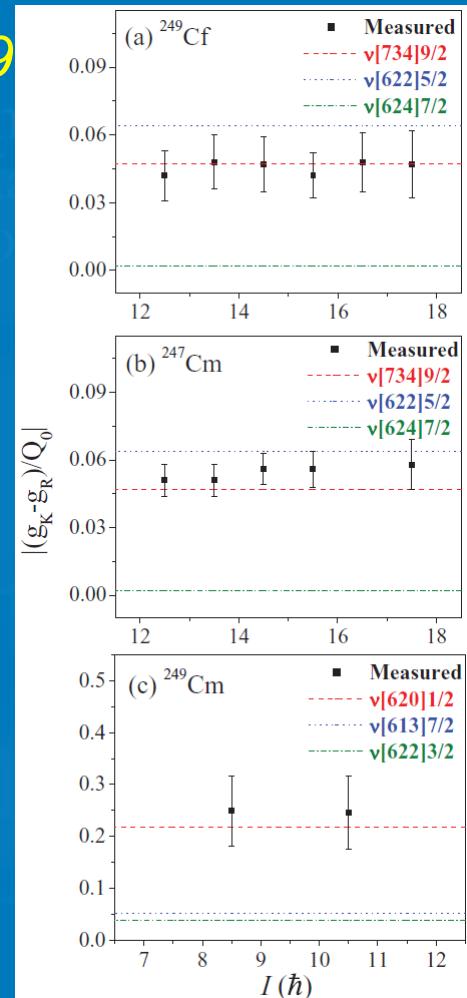


^{209}Bi on ^{248}Cm , ^{207}Pb on

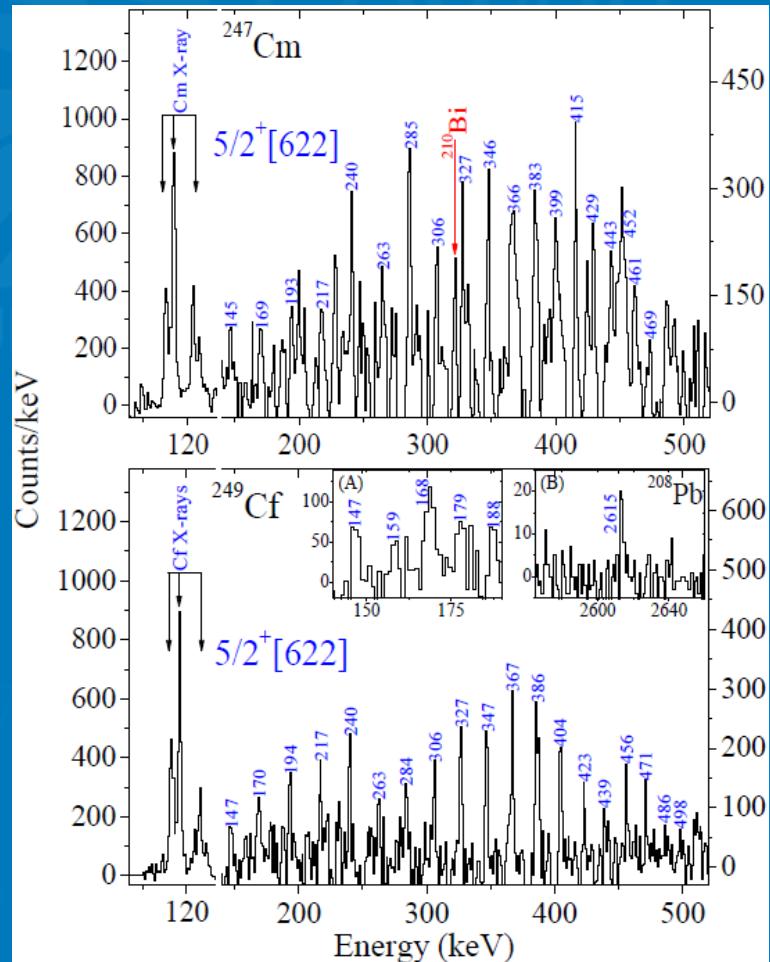
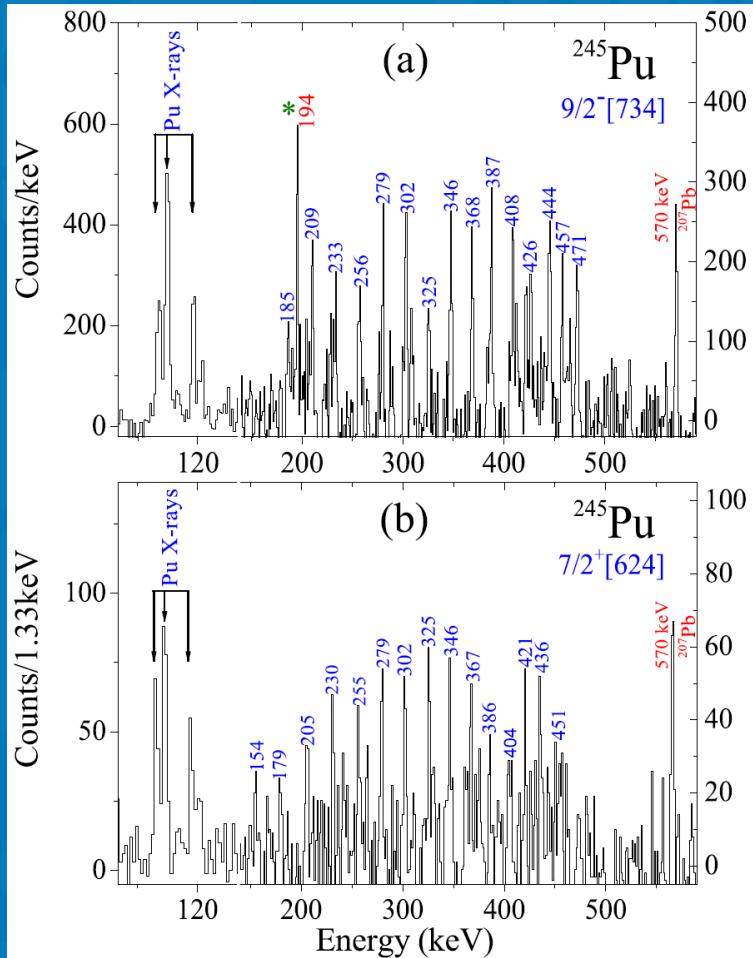
249

$N = 151$,
 $9/2^+[734]$
 $N = 153$,
 $1/2^+[620]$

Configuration assignments
from $B(M1)/B(E2)$
branching ratios

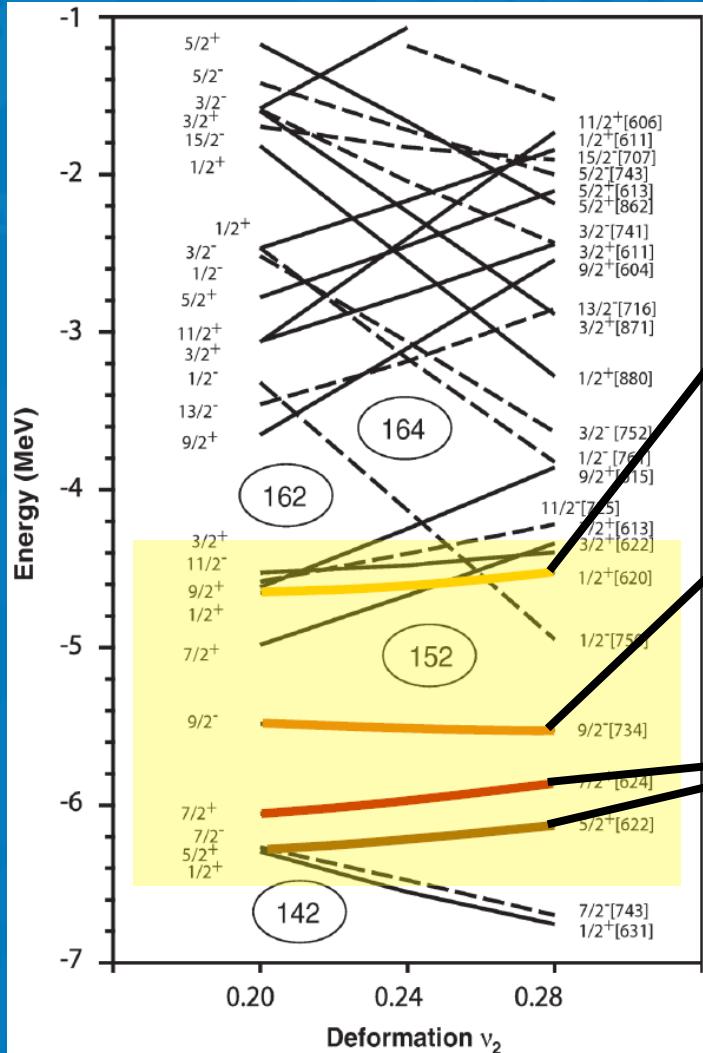


w bands – ^{245}Pu , ^{247}Cm and ^{249}Cf ($N = 151$)



Manuscript in preparation, S. S. Hota *et al.*

Neutron single-particle orbitals around $N =$



$1/2[620]$ - ground state

$N = 153$ isotope
 ^{249}Cm

$9/2[734]$ - ground state

$N = 151$ isotones
 $^{245}Pu, ^{247}Cm, ^{249}Cf$

$7/2[624]$ and $5/2[622]$

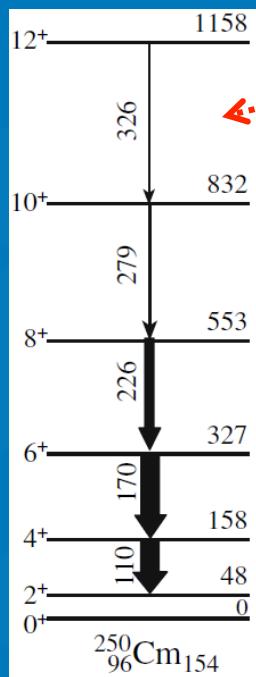
Excited bands

$N = 151$ isotones
 $^{245}Pu, ^{247}Cm, ^{249}Cf$

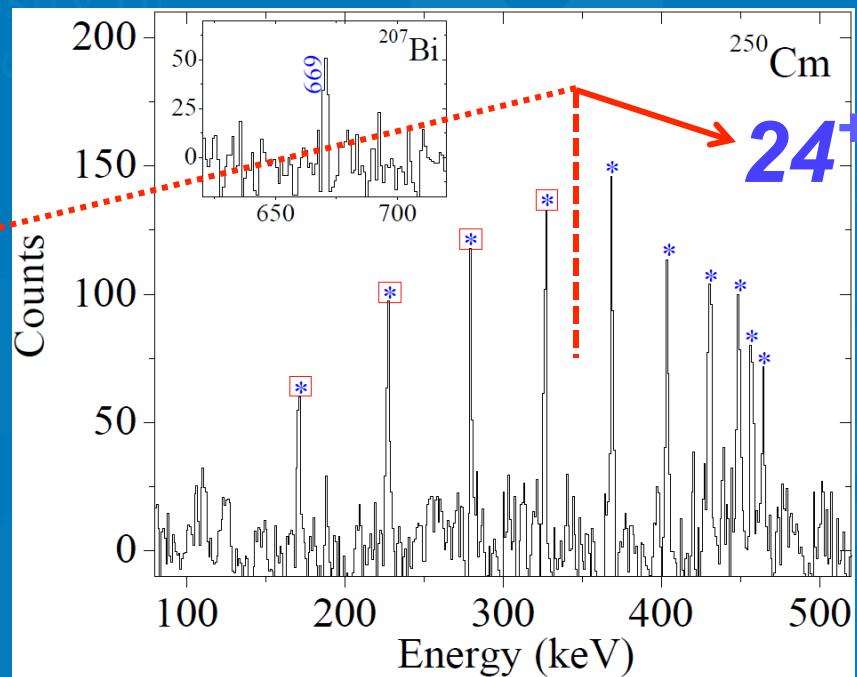
Ahmad & Chasman, PRC 80, 064315 (2009)

ground state band in $N = 154$ isotones

18O on ^{248}Cm



^{209}Bi on ^{248}Cm

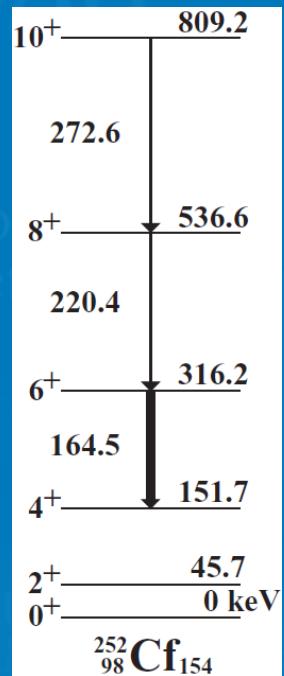


Manuscript in preparation, S. S. Hota *et al.*

*T. Ishii et al., ^{208}Pb (1460 MeV) on ^{251}Cf performed
PAN 70, 1457 (2006)*

Sankha Hota

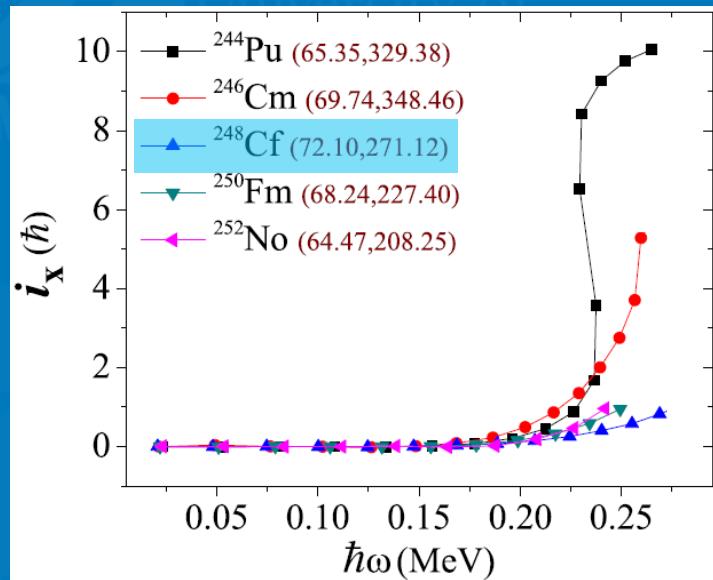
Nuclear Structure 2012, ANL



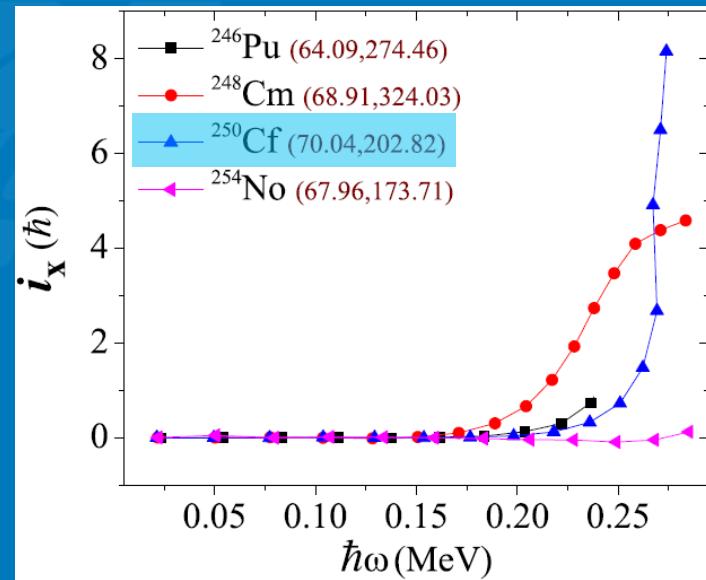
R.
Takahashi
et al., PRC
81,
570B
(2010)

Systematics for $N = 150, 152$ isotones

$N = 150$



$N = 152$



$i_{13/2}$ protons in ^{244}Pu

Complete, only in Pu

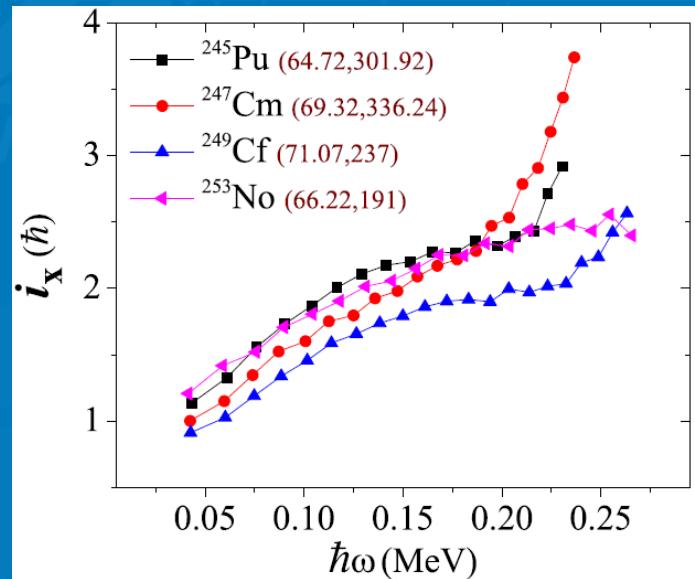
$\pi i_{13/2}$ or $\nu j_{15/2}$ in ^{250}Cf ?

Clues, the odd- N nuclei

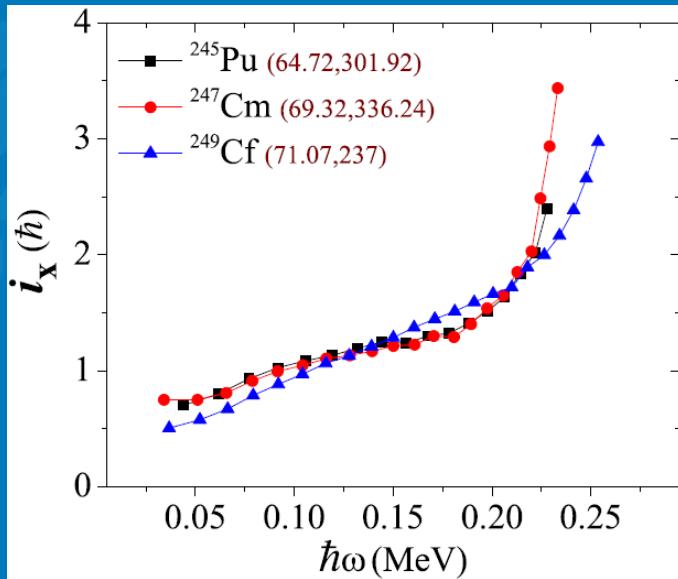
^{248}Cf is interesting !

Systematics for $N = 151$ isotones

GS Bands



Excited Bands



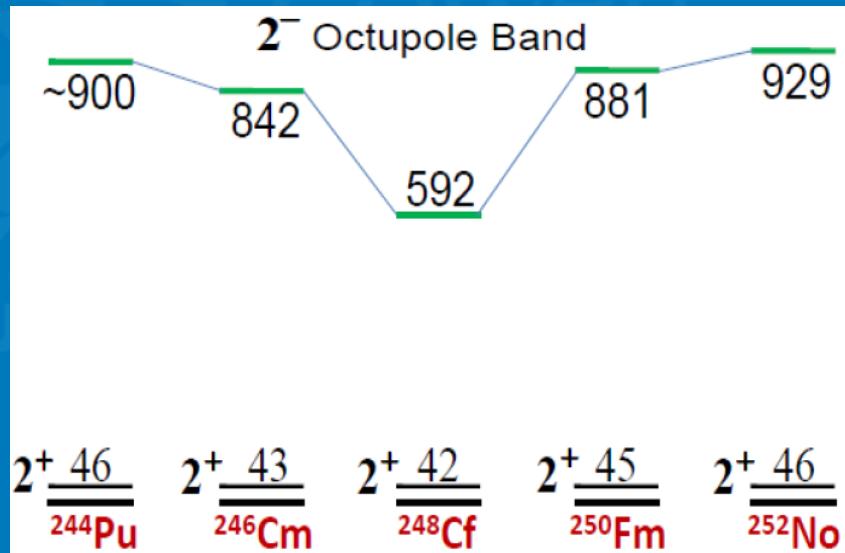
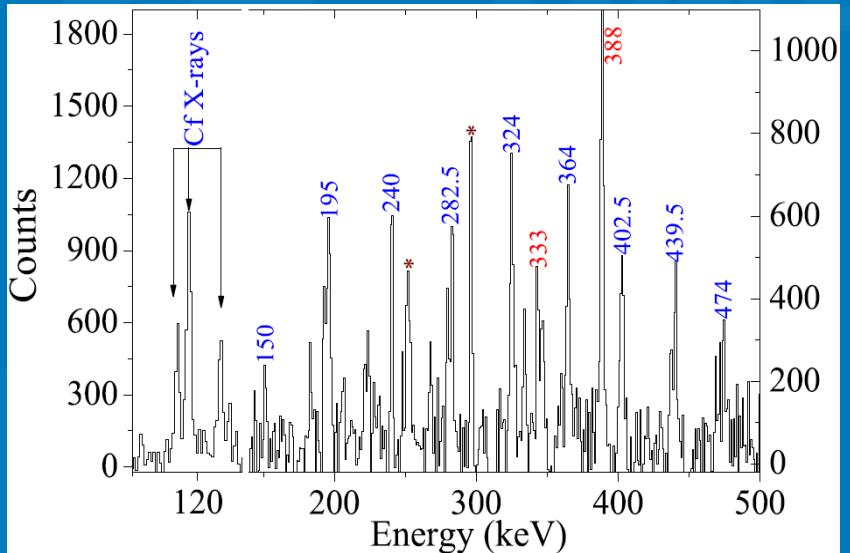
Built on $9/2[734]_v$

$7/2[624]_v$, $5/2[622]_v$

$j_{15/2}$ neutrons are blocked $j_{15/2}$ neutrons, $i_{13/2}$ protons

Results suggest negligible $j_{15/2}$ neutrons contribute

Octupole band in ^{248}Cf



Cf X-rays

Out of band E1 transitions

Strong population

Similar to ^{240}Pu

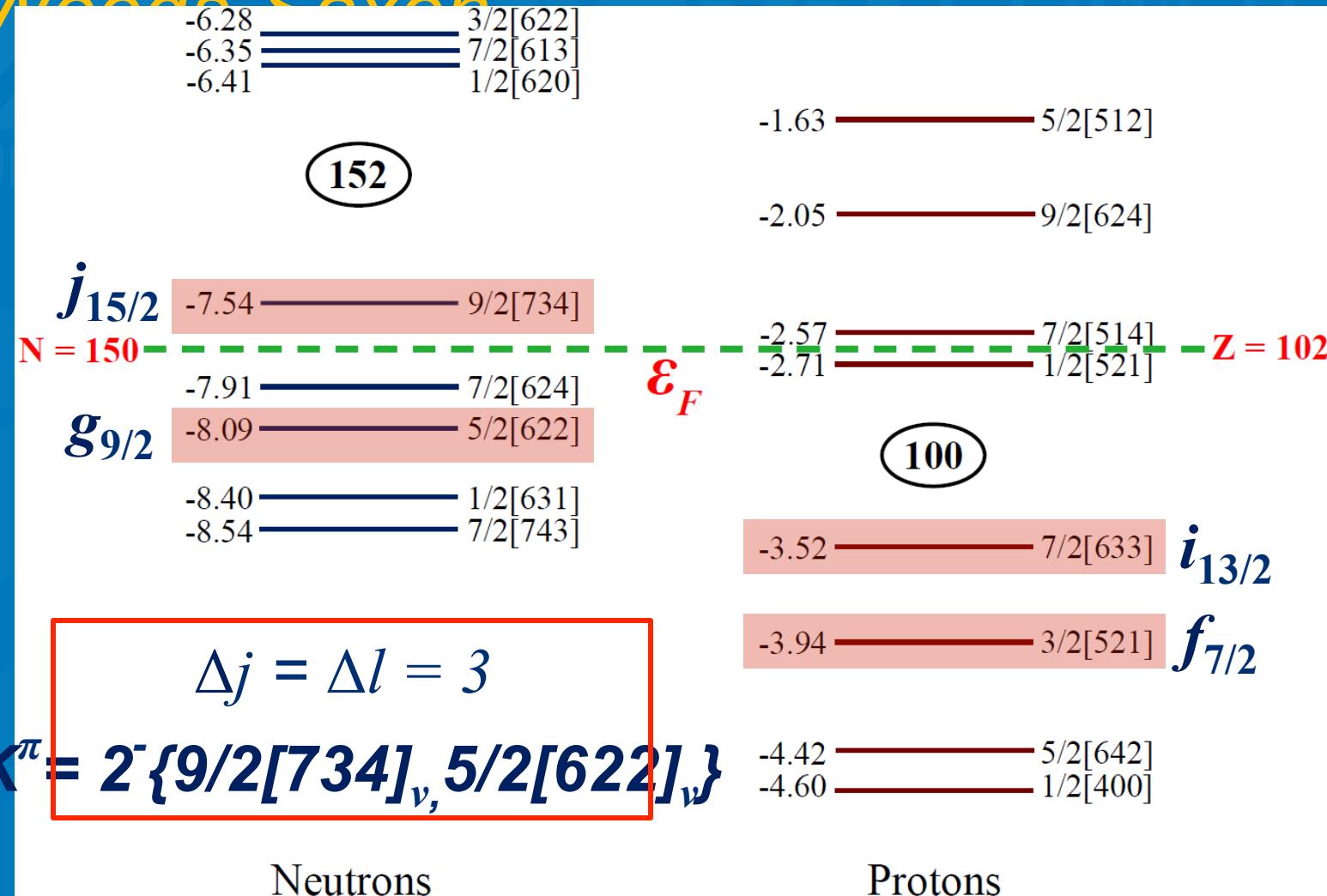
Lowest 2^+ energy in actinides

Lowest 2^- octupole bandhead

No alignment $\geq 26^+$

Single-particle energies –

Woods-Saxon



Comparison with ^{240}Pu

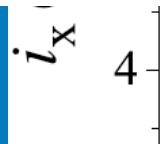
VOLUME 83, NUMBER 11

PHYSICAL REVIEW LETTERS

13 SEPTEMBER 1999

Octupole Correlations in the Pu Isotopes: From Vibration to Static Deformation?

I. Wiedenhöver,¹ R. V. F. Janssens,¹ G. Hackman,² I. Ahmad,¹ J. P. Greene,¹ H. Amro,^{1,3} P. K. Bhattacharyya,⁴ M. P. Carpenter,¹ P. Chowdhury,⁵ J. Cizewski,^{1,6} D. Cline,⁷ T. L. Khoo,¹ T. Lauritsen,¹ C. J. Lister,¹ A. O. Macchiavelli,⁸ D. T. Nisius,¹ P. Reiter,¹ E. H. Seabury,⁵ D. Seweryniak,¹ S. Siem,^{1,9} A. Sonzogni,¹ J. Uusitalo,¹ and C. Y. Wu⁷



PRL 102, 122501 (2009)

PHYSICAL REVIEW LETTERS

week ending
27 MARCH 2009

Structure of ^{240}Pu : Evidence for Octupole Phonon Condensation?

X. Wang,^{1,2,*} R. V. F. Janssens,¹ M. P. Carpenter,¹ S. Zhu,¹ I. Wiedenhöver,³ U. Garg,² S. Frauendorf,² T. Nakatsukasa,⁴ I. Ahmad,¹ A. Bernstein,³ E. Diffenderfer,³ S. J. Freeman,^{1,5} J. P. Greene,¹ T. L. Khoo,¹ F. G. Kondev,⁶ A. Larabee,⁷ T. Lauritsen,¹ C. J. Lister,¹ B. Meredith,⁷ D. Seweryniak,¹ C. Teal,³ and P. Wilson³

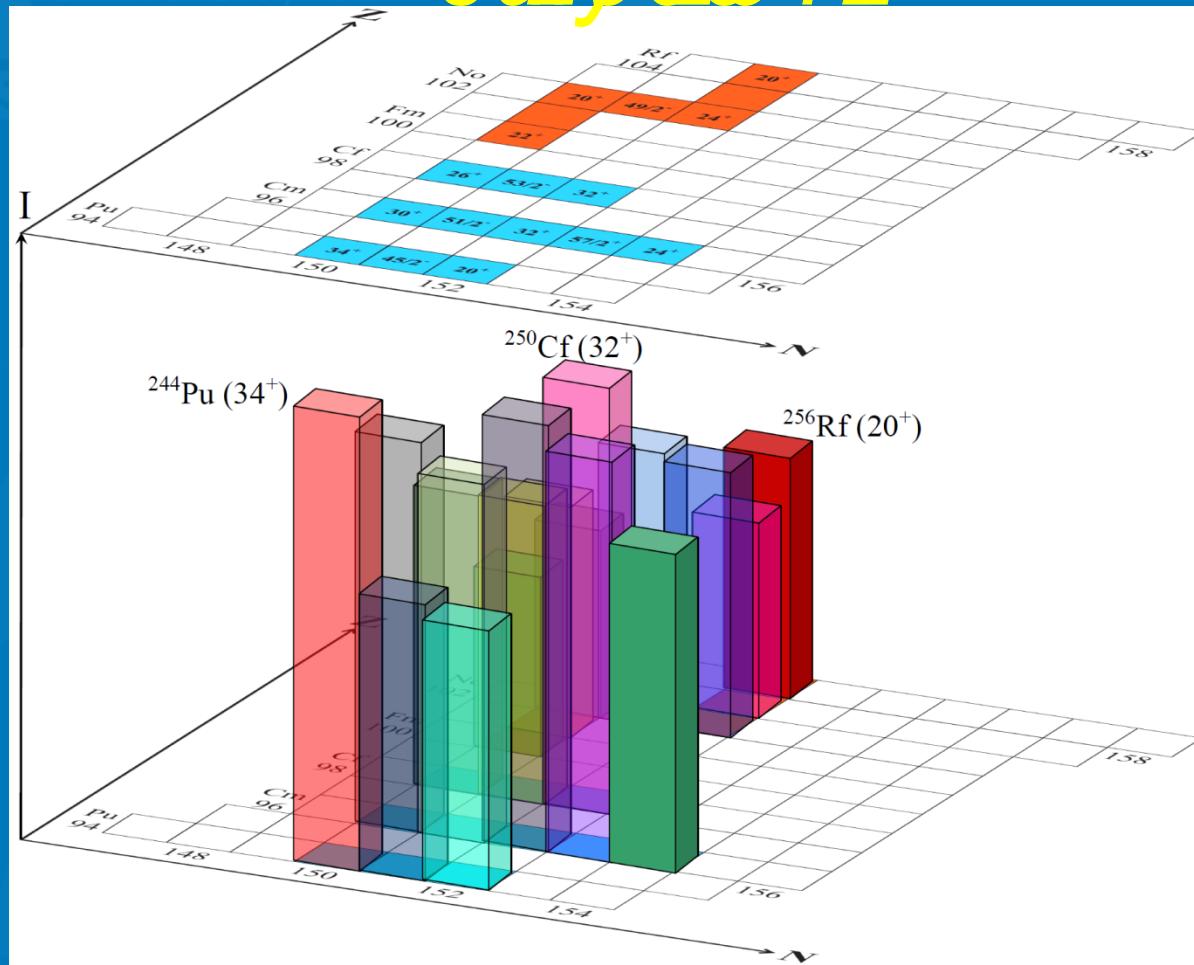
*B(E1, out of band)/B(E2, in band)
branching ratios for the octupole band*

Summary and outlook

- ❖ *High-spin rotational bands - new or extended in neutron-rich $^{244,245,246}\text{Pu}$, $^{246,247,250}\text{Cm}$ and $^{248,249}\text{Bk}$*
- ❖ *Systematic investigation of neutron single-particle orbitals in the highest oscillator shells*
- ❖ *Detailed picture of particle alignments: contribution of $i_{13/2}$ protons and $j_{15/2}$ neutrons*
- ❖ *No alignment in ^{248}Cf , lowest 2^+ and $K^\pi = 2^-$ energy levels? Effect of Octupole correlation ?*
- ❖ *Future : exploration of proton single-particle orbitals*

Changing landscape of $A \sim 250$ region

July 2012



Collaboration

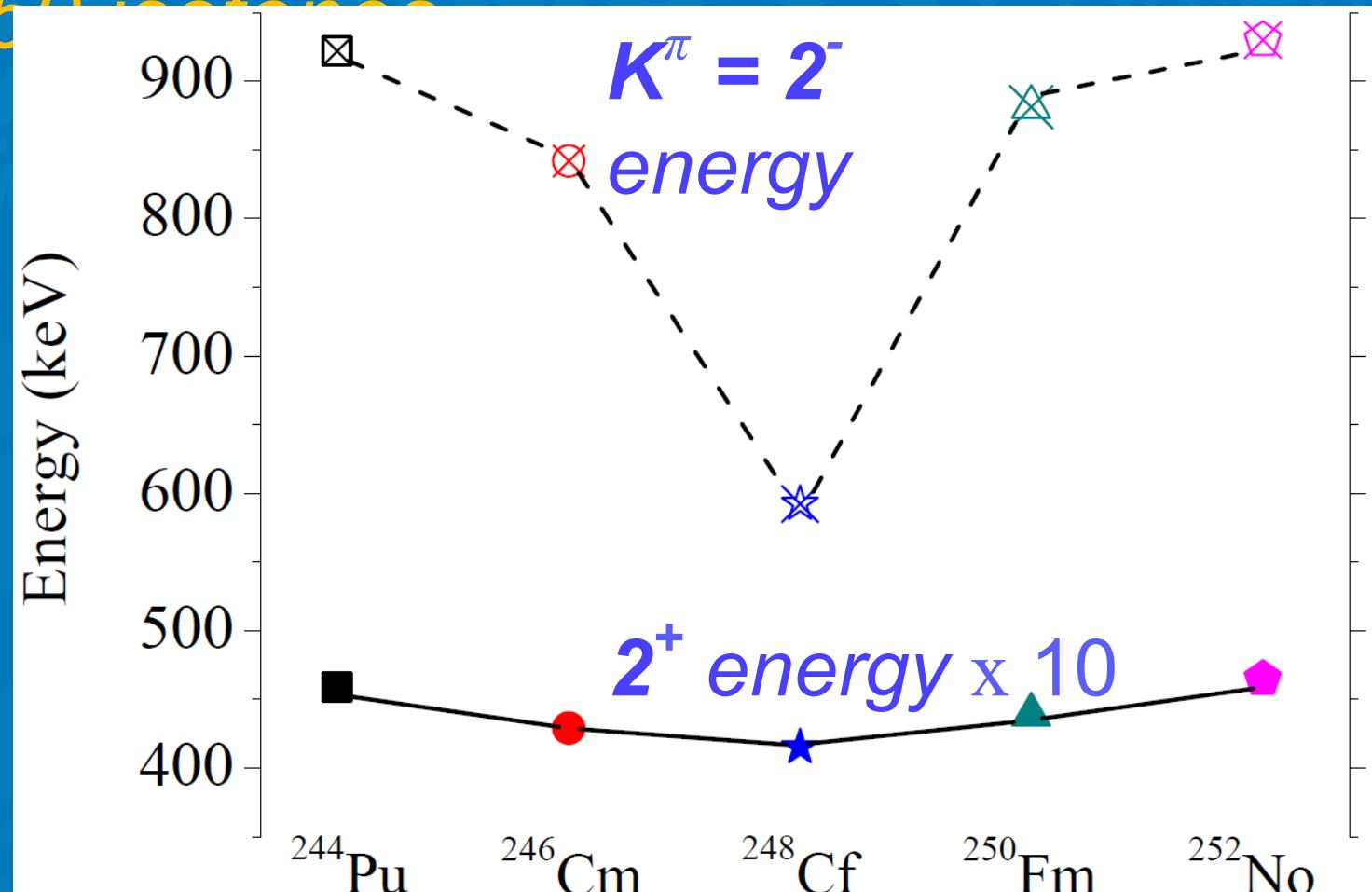
S. S. Hota.¹, P. Chowdhury¹, T.L. Khoo², M.P. Carpenter², R.V.F. Janssens², I. Ahmad², J. P. Greene², S.K. Tandel^{1,3}, D. Seweryniak², S. Zhu², C.J. Chiara^{2,4}, A. Y. Deo¹, N. D'Olympia¹, C. J. Guess¹, G. Henning², C.R. Hoffman², E. G. Jackson¹, F.G. Kondev², S. Lakshmi¹, T. Lauritsen², C.J. Lister¹, E.A. McCutchan², C.K. Nair², V.S. Prasher¹, Y. Qiu¹, U. Shirwadkar¹, I. Stefanescu²

¹University of Massachusetts Lowell

²Argonne National Laboratory

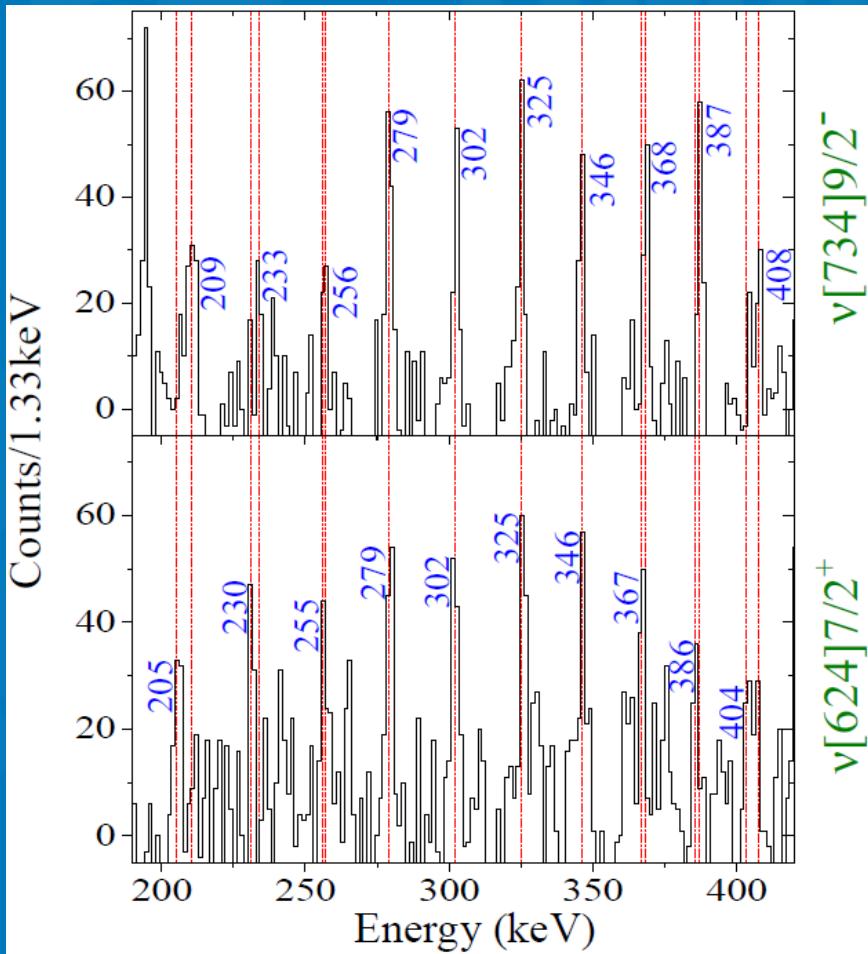
2^+ and 2^- energies in $N =$

150 isotopes

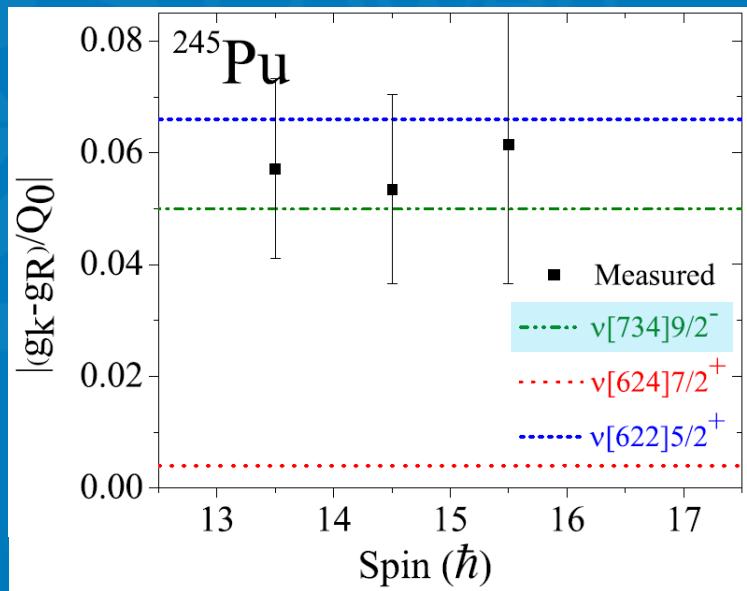


Dip at ^{248}Cf

Results – ^{245}Pu GS [734] and [624] bands



GS and Excited Bands



Large error bars
Low statistics

[622] not possible
Higher excitation energy